

The Delphi logo is displayed in a bold, black, sans-serif font. It is positioned on the right side of a horizontal band that has a blue gradient background with abstract, light-colored streaks or rays emanating from the left. The band itself is a lighter shade of blue, contrasting with the darker blue background above and below it.

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SOFC Technology R& D Needs

Steven Shaffer

Chief Engineer – Fuel Cell Development

DOE Pre-Solicitation Workshop

January 23 & 24, 2008

Solid Oxide Fuel Cell Market Opportunity



Heavy Duty Truck
Diesel



Recreational Vehicles
Diesel, LPG



Truck and Trailer Refrigeration
Diesel



US Military
JP-8



**European micro –CHP
& CHCP**
Natural Gas



US Stationary – APU & CHP
Natural Gas, LPG



Commercial Power
Natural Gas



FutureGen Powerplant
Coal Gas

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Heavy Duty Truck Market Drivers: Increasing Cab Electrical Loads



Margaret Sullivan, PACCAR
[Topic: Truck of the Future](#)
2003 Conference Proceedings
Fourth Annual SECA Meeting - Seattle, WA
April 15-16, 2003

In-Cab Appliances Include

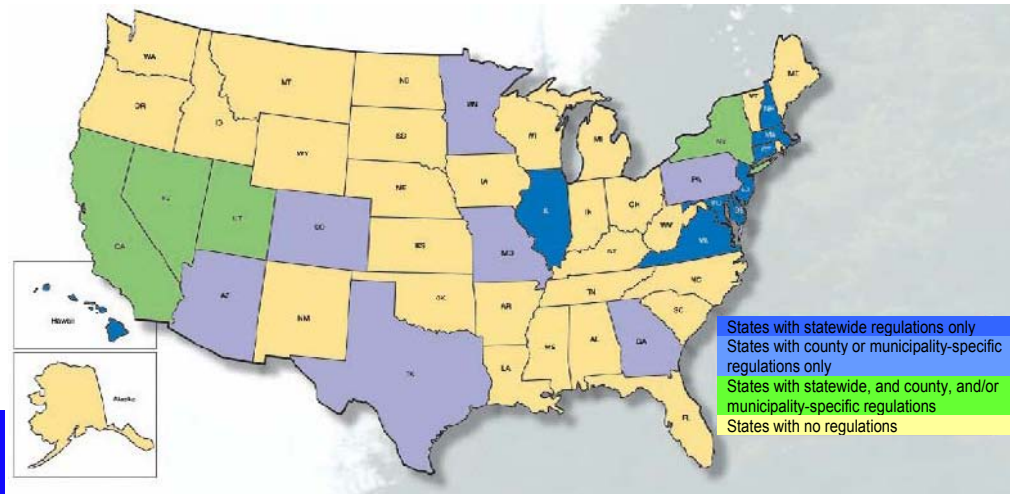
- CB Radios
- Cell Phones
- Televisions
- Refrigerators
- Stereos
- Lamps
- DVD / VCR Player
- Computer
- Microwave
- Coffee Maker
- Electric Blankets
- Electric AC / Heater

*Truck load profiles identify potential
power requirements of 2.5kW to 4.0kW*

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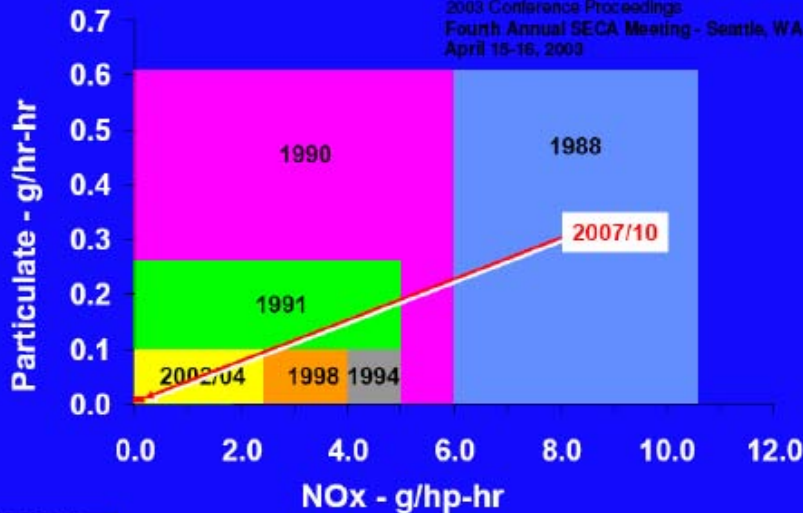
Heavy Duty Truck Market Drivers: Increasingly Stringent Emission & Anti-Idling Regulations

Annually, long-duration truck and locomotive engine idling...



2007 Emissions

Margaret Sullivan, PACCAR
[Trucks: Truck of the Future](#)
2003 Conference Proceedings
Fourth Annual SECA Meeting - Seattle, WA
April 15-16, 2003



... Emits 11-million tons of CO₂, 200,000 tons of NOx, and 5,000 tons of particulate matter

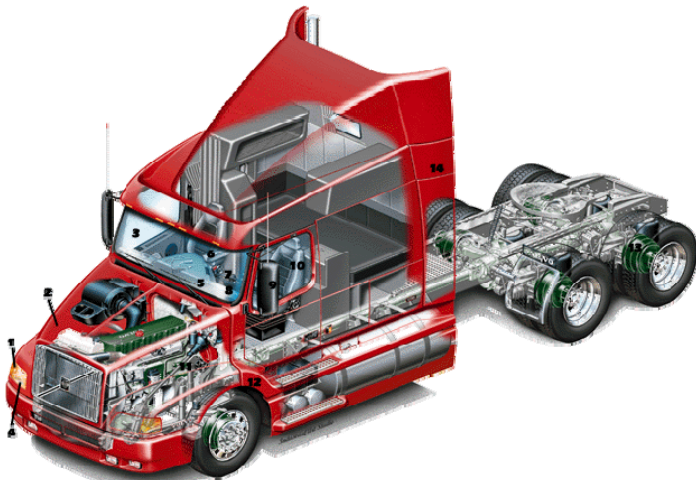
... Consumes >1-billion gallons of diesel fuel

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Heavy Duty Vehicle APU Industry Collaboration

- ◆ Delphi has teamed with DOE EERE and OEM's PACCAR Incorporated and Volvo Trucks North America (VTNA) to define system level requirements for a Fuel Cell (SOFC) based Auxiliary Power Unit (APU) for the commercial trucking industry.

VOLVO



**Volvo Trucks North America (VTNA),
Greensboro, NC**

PACCAR



Foden Trucks
A Division of PACCAR U.S.A. Inc.



PACCAR, Mt. Vernon, WA

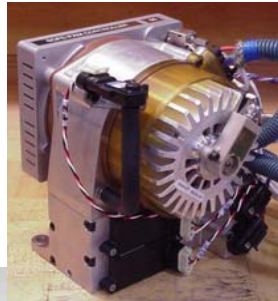
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Solid Oxide Fuel Cell Power Systems

Sensors



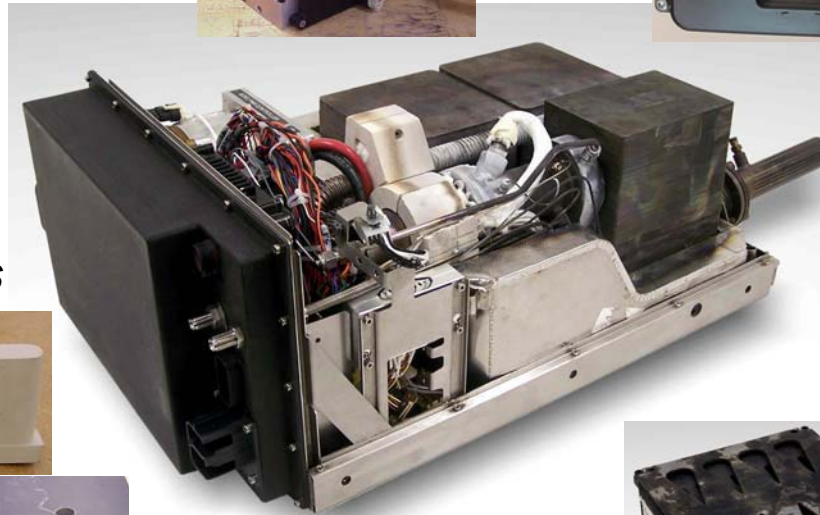
Blowers



Electronics & Controls



Heat Exchangers



Stack & Reformers
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Cell and Stack Development
Funded by
Solid State Energy Conversion Alliance
(SECA)

Research Priorities: SECA Cost Reduction

<p>Risk Level</p> <p>Low</p> <p>Moderate</p> <p>High</p>	Gas Seals	<ul style="list-style-type: none"> Glass and Compressive Seals Compliant Seals Self-healing Materials High Temperature Seal Brazes
	Failure Analysis	<ul style="list-style-type: none"> Models with Electrochemistry Define Operating Window Structural Failure Analysis & Design Criteria
	Cathode performance	<ul style="list-style-type: none"> Optimize Microstructure Mixed Conduction New Active Materials Understand Mechanism <ul style="list-style-type: none"> Ad-atom Modification of Surface Modification through Infiltration
	Interconnect	<ul style="list-style-type: none"> Coatings Electrode to Interconnect Interface Contact Material Inexpensive Processing/Removal of Tramp Elements
	Anode / fuel processing	<ul style="list-style-type: none"> Catalyst Surface Modification Characterize Thermodynamics/Kinetics/ Contaminants Multi-component Catalysts
	Heat Exchangers/ High Temperature Blowers	<ul style="list-style-type: none"> Cost and Reliability Design Guidelines



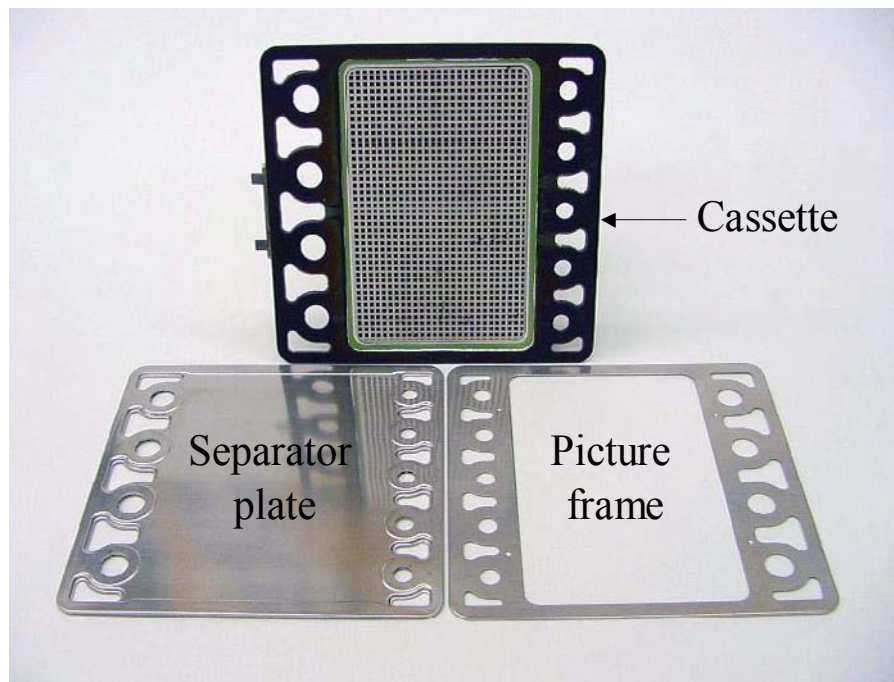
Surdoval, 2007 SOFC X

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SOFC Stack Development

◆ Key Stack Characteristics

- Cassette repeating unit configuration
- High volume manufacturable processes (stamping, laser-welding, etc)
- Integrated manifold and compact load frame
- Low mass and volume



Generation 3 (30 cell),
9 Kg, 2.5 L

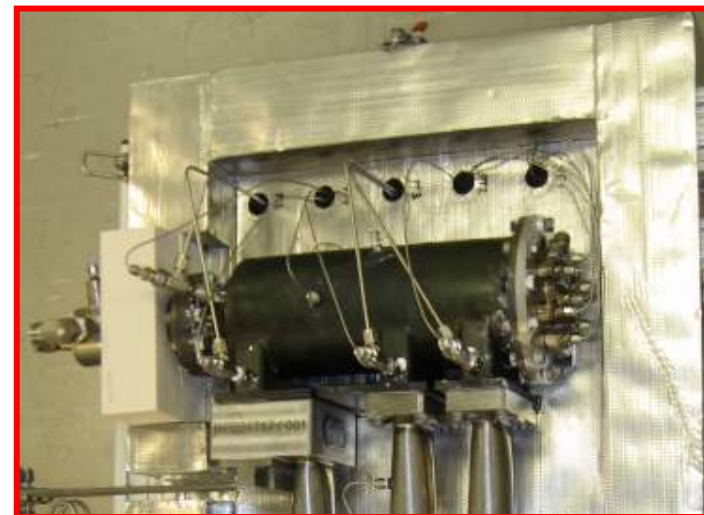
The logo for DELPHI, featuring the word in a bold, black, sans-serif font. The logo is positioned on the right side of a horizontal band that transitions from a dark blue background on the left to a lighter blue background on the right.

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Subsystem Development
Reformer

Fuel Reformer Development

- ◆ Development of reforming technology for Natural Gas, Gasoline and Diesel/JP-8 for SOFC applications
- ◆ Two main technologies are being developed:
 - **CPOx Reformer**
 - » Moderate efficiency
 - » Simplicity of design
 - » Not recycle capable
 - **Steam Reformers**
 - » High efficiency
 - » Use of water to accommodate steam reforming
 - » Recycle capable



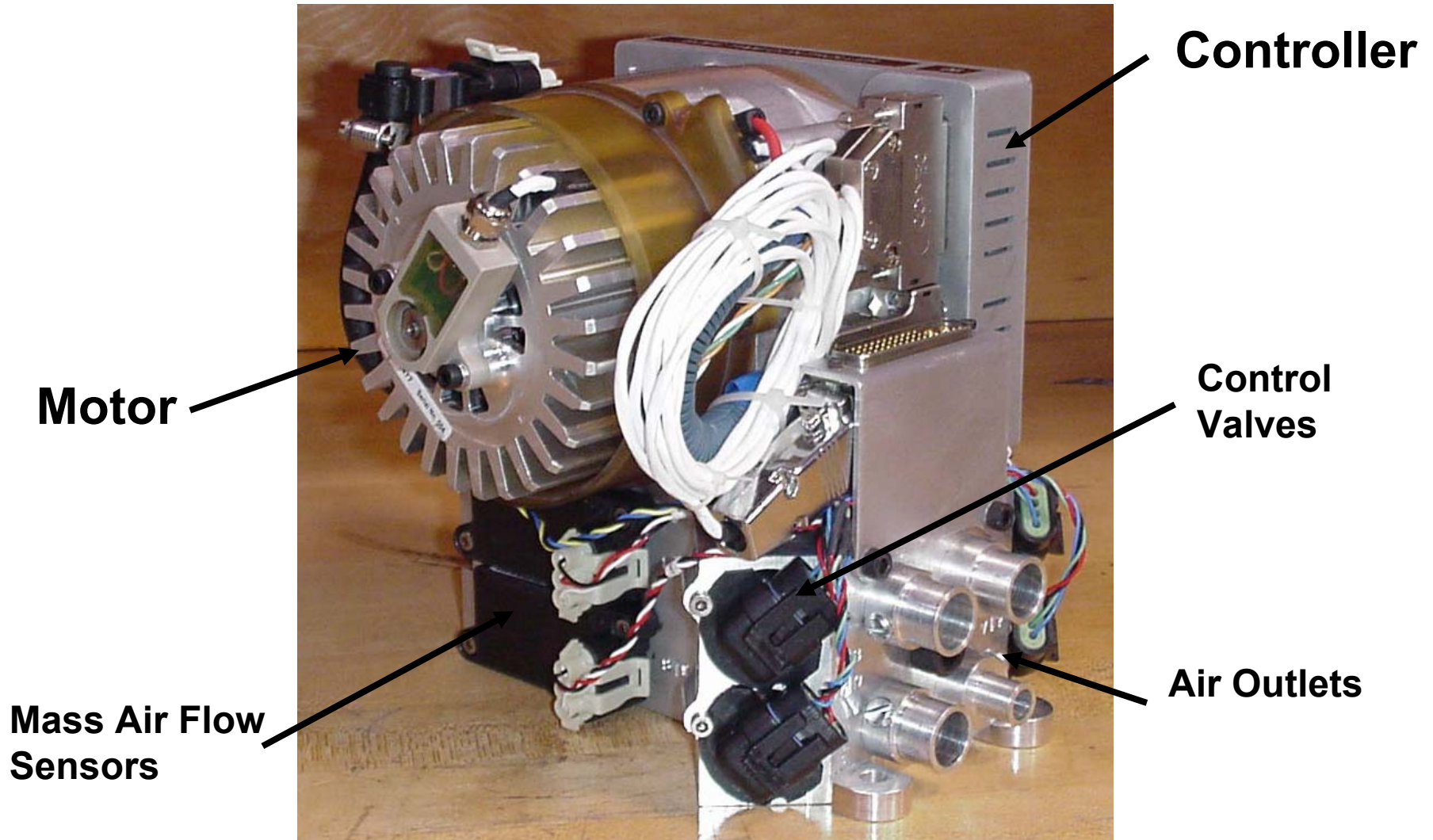
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Subsystem Development
Balance of Plant Components

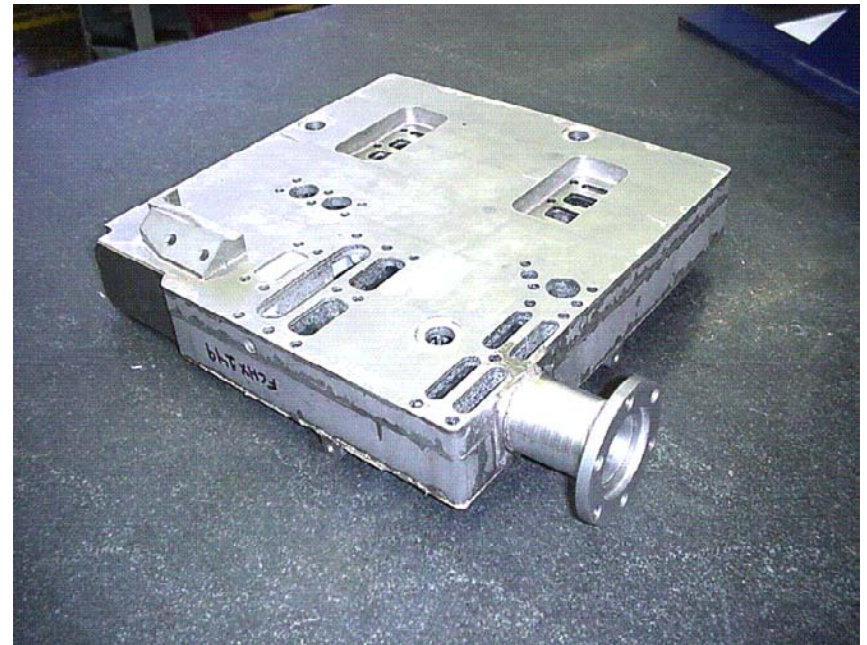
Air Supply Sub-System



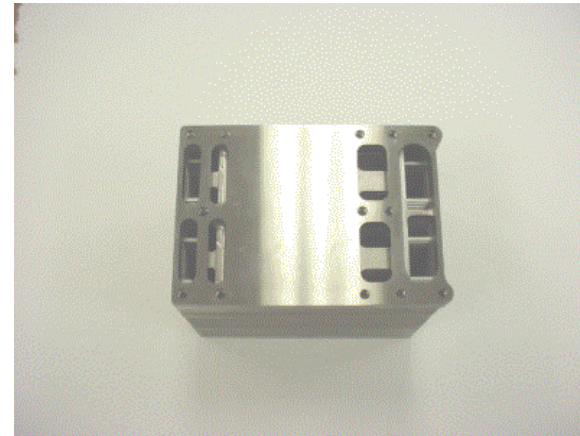
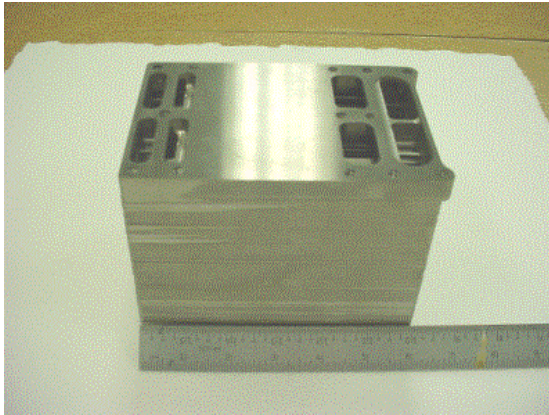
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High Temperature Manifolds

- Manifold serves as structural mounting surface for Stacks, Reformer and Cathode Air Heat Exchanger
- Routes gases to and from components
- Facilitates small package size



High Temperature Heat Exchangers



Cathode Air Heat Exchanger



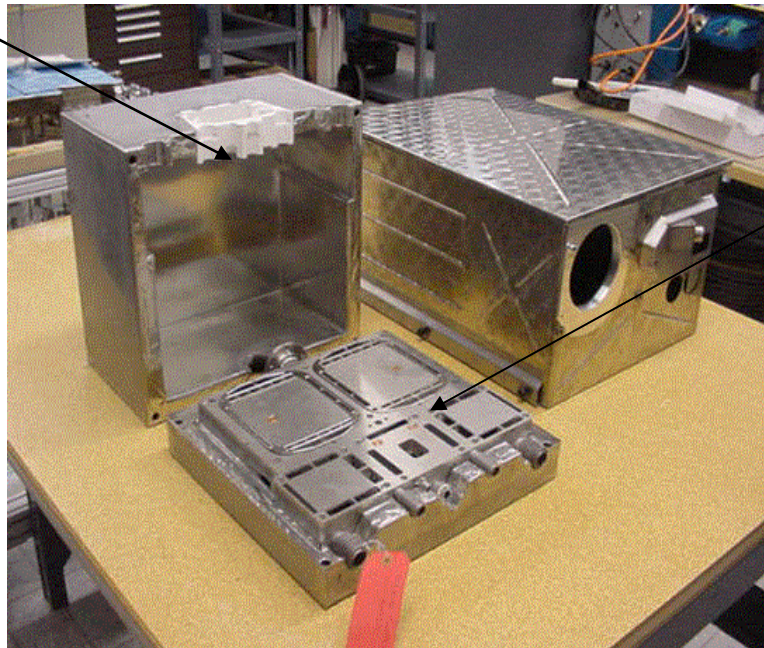
Anode Tailgas Recycle Cooler

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High Temperature Insulation

- Thermal Insulation
 - An example is micro-porous Insulation, metal wrapped using standard manufacturing process

Insulation
Shell



Integrated
Component
Manifold

Power Electronics Components

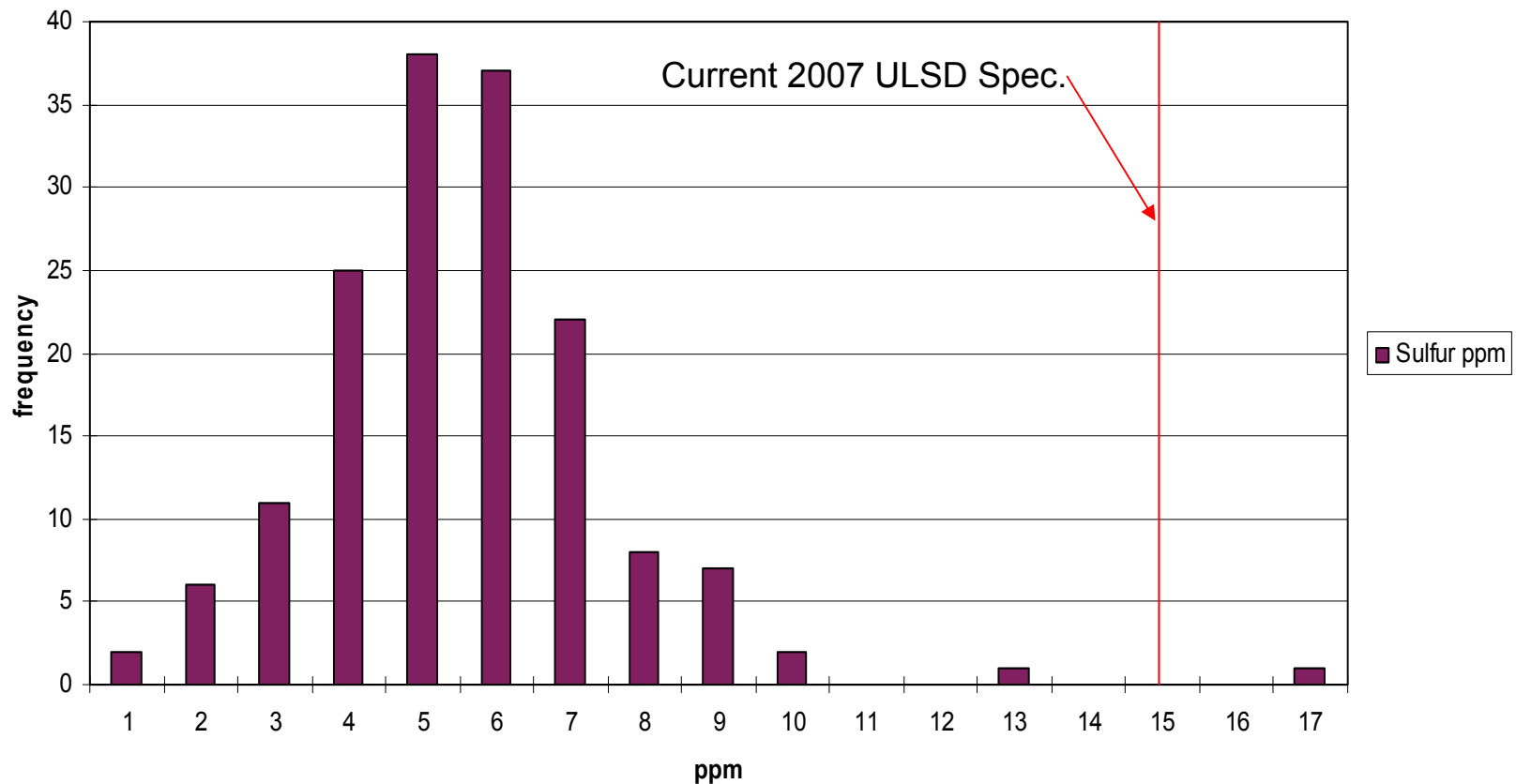
- DC to DC Converters
- DC to AC Inverters



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Diesel Fuel Survey Results

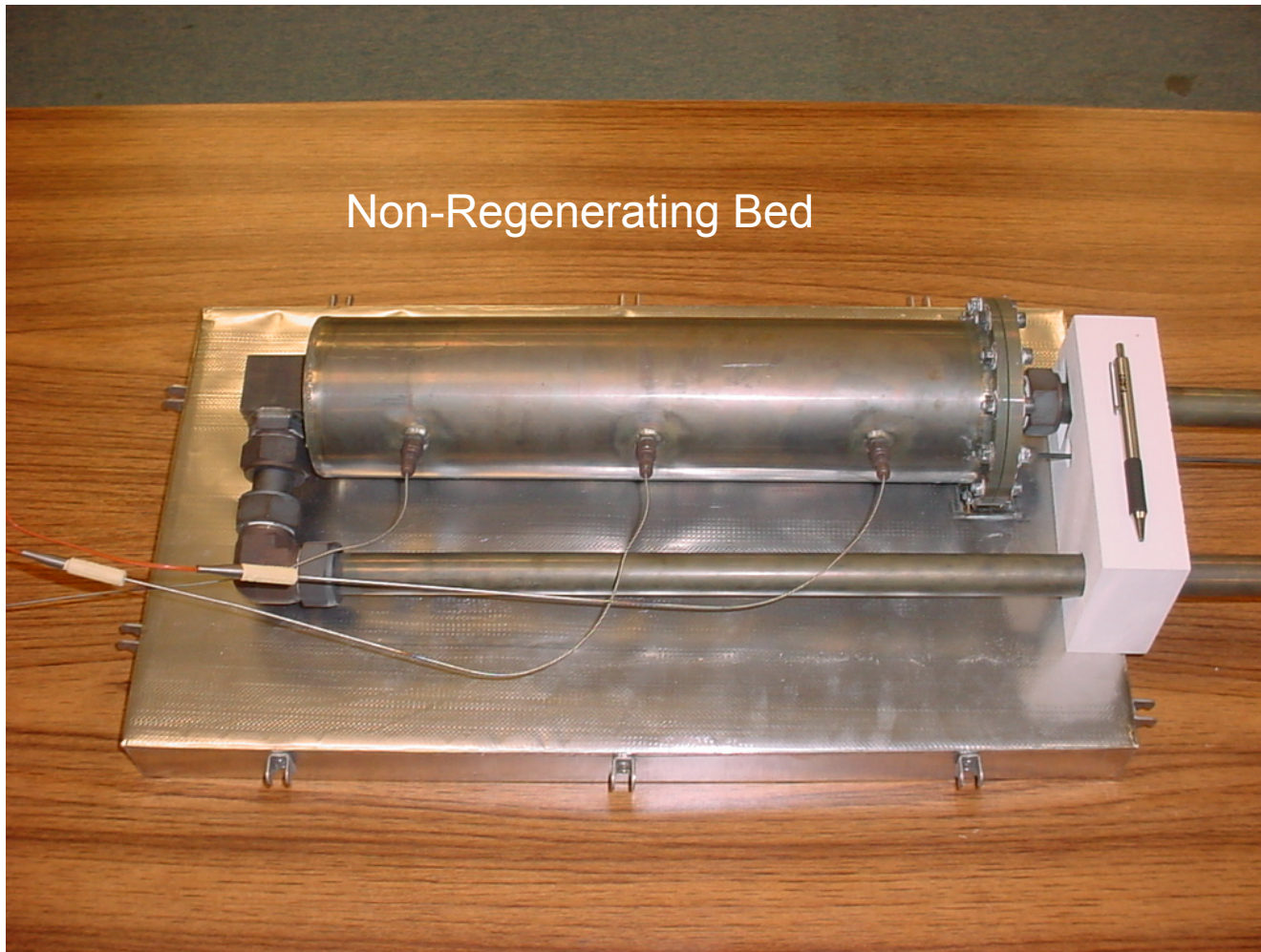
Summer 2007 – Sulfur Levels



Source: Alliance of Automobile Manufacturers (US and Canada, 160 samples)

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Hot Reformate Desulfurizer



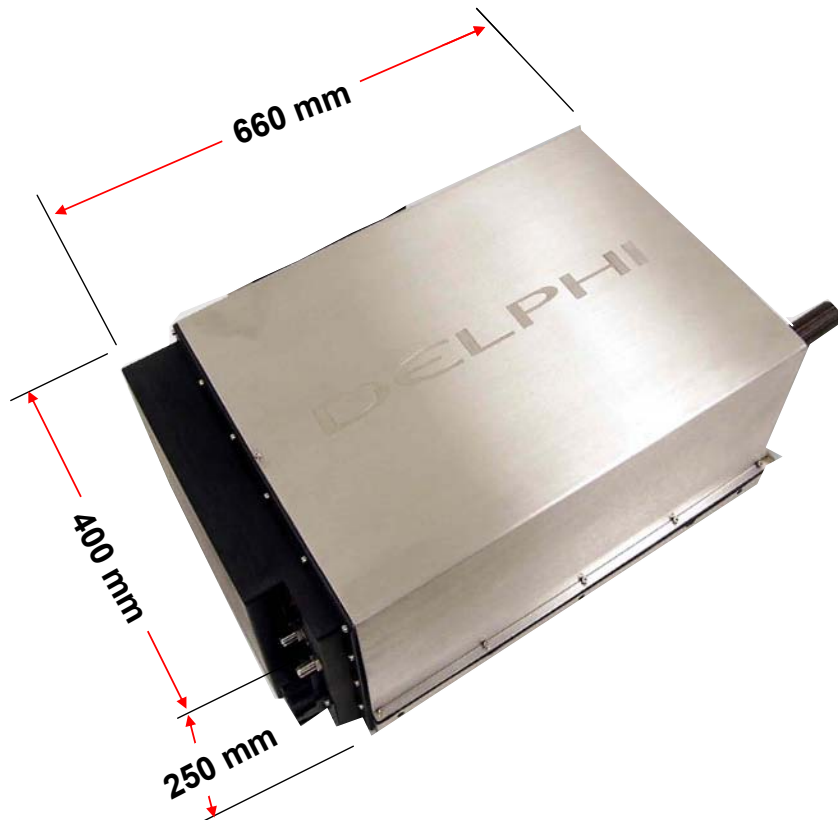
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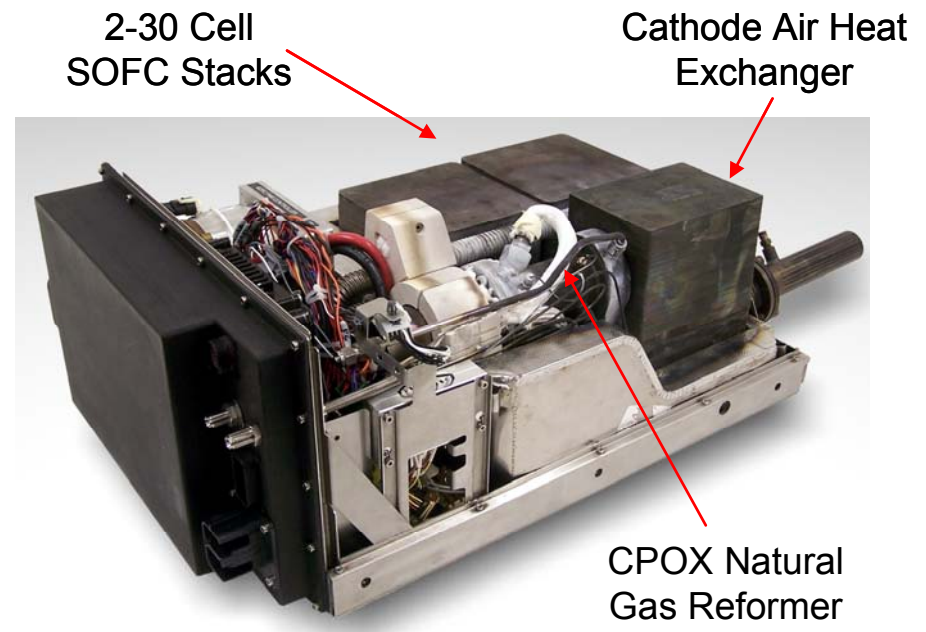
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SOFC System Integration

Solid Oxide Fuel Cell Power System



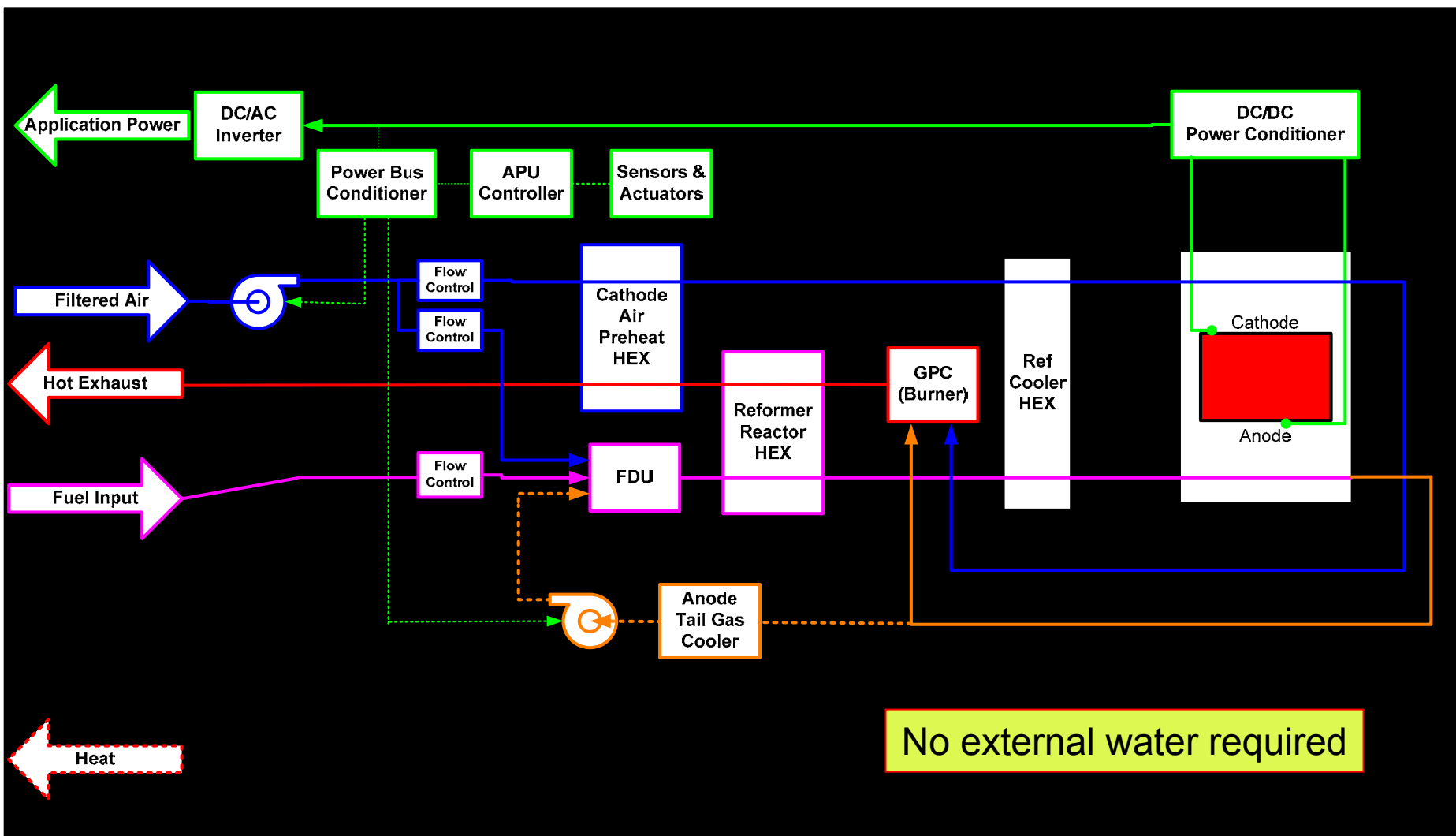
***60-Liter Displacement
85-kg Weight***



- Leading edge packaging
- High gravimetric & volumetric power density

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SOFC System Mechanization With Anode Tail Gas Recycle



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Summary

- Areas of Development for Small Power Plants
 - Fuel Reformers
 - Desulfurizers
 - Balance of Plant Components
 - Power Electronics
 - System Integration
 - Applications Engineering